PERMEABILITY CHARACTERISTICS OF TROPICAL SOILS AT UTP CAMPUS

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CIVIL ENGINEERING
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CERTIFICATION OF APPROVAL

Permeability Characteristics of Tropical soils at UTP Campus

By

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ABSTRACT

Soil permeability varies spatially and this spatial variability causes difficulty to representing a soil with a deterministic or precisely defined set of permeability value. In Malaysia, the studies on the spatial variability of soil permeability are limited. This study examines the spatial variability of soil permeability in UTP campus area located in Tronoh. The objective is to map the variation in soil hydraulic characteristics in the study area. Statistical and geostatistical method was used in this study. 50 soils sample were collected on the field from predefined geo-grid location.

GPS (Global Positioning System) is used to determine the reference points for the making of the the geo-grid sampling locations. Samples were then taken to the laboratory for analysis. The method that used to measure the permeability of the soil samples was The Falling Head Permeability test. Laboratory test result were then subjected to statistical and geostatistical analysis. Digitizing Software was used to digitize the map of the study area. Geostatistical characterization was performed by the GS+ and Surfer Software. Kriging method is used for the interpolation of the ensample location and preparing map of the spatial variability of the permeability rates in UTP campus area is prepared.

Besides, it also can allows mapping of the spatial distribution and the normal statistics will helped in identifying causes of the variability in the soil permeability. Others, even the semivariogram shows the consistent result, however the relatively low r^2 (0.638) show poor fit to data. This is because in the fact that the number of the sample is not enough for that extend of area studied.

The significant variation of soil permeability exists in the area of studied are shown in the result. Larger range and the lower sill indicates that the soil permeability are spatially dependent over long distance (large range) and the variability is low (indicates by low sill). Land disturbance and land topographic conditions donate to the variability of soil permeability.

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CHAPTER 1: INTRODUCTION

1.1 Background of study

Permeability is that property of the soil which permits water to flow through it through its void. Soils with large voids are more permeable than those whose voids are small. Furthermore, since most soils with large voids usually have large void ratios, it may deduced that, other factor notwithstanding, permeability increase with increasing void ratios.

Soil is a natural body consisting of layers (soil horizons) of mineral constituents of variable thicknesses, which differ from the parent materials in their morphological, physical, chemical, and mineralogical characteristics. It is well known that when the water is applied to the surface of soil, a part of it seeps into the soil. This movement of the water through soil surface is known as hydraulic conductivity.

Hydraulic conductivity is a property of soil or rock that describes the ease with which water can move through pore spaces or fractures. Permeability of soil is a measure of the ability the soil to transmit fluids. The Schlumberger Excellence in Educational Development (SEED, 2009) stated that soil permeability as the property of soil pore system that allows fluid to flow. The factor that determines whether a soil has high or low permeability is generally the pores sizes and their connectivity.

Soil hydraulic (permeability) characteristics vary spatially and temporally from a field scale to a large regional scale and are influenced by both intrinsic (e.g. soil formation process, composition of parent rocks, soil organisms) and extrinsic (e.g. regional climate, vegetation, soil management practices, fertilization, etc.).

Spatial variability causes difficulty in representing a soil with a deterministic or precisely defined set of characteristic and precludes characterization of soil hydrological response. Once the major issues in distributed parameter hydrological modeling is how to estimate attributes of spatially varying soil nutrients.

This proposed project will allow understanding and characterization of small scale spatial variability nature of permeability characteristics of tropical soil at Universiti Teknologi PETRONAS campus area.

1.2 Problem Statement

Among the engineering problem where soil permeability may play quite prominent role are:

1. Quantity of leakage through and under dams
2. Rate of consolidation and related settlement
3. Infiltration into and dewatering of deep excavation
4. Stability of slope, embankment, hydrostatic uplift evaluation
5. Seepage velocity through the soil may create erosion via transportation of fine-grained particles.

Soil and groundwater contamination by various hazardous substances is a worldwide environmental problem. Contaminant concentrations in environmental media can be monitored. However, environmental monitoring is quite expensive and time consuming. Various simulation models have been developed for assessment of groundwater vulnerability to contamination resource management, and design of monitoring programs. In order to apply numerical models, the hydraulic properties of the soils must be determined. The soil-water retention and hydraulic conductivity curves are basic soil hydraulic properties describing water behavior in soils.

Main factor of plant growth, nutrient cycling and contaminant transport are the soil hydraulic and flow dynamic of the soil. In particular, permeability is a dominant process controlling the soil water status for plant and zone of transport of pesticides and nutrients. The permeability rate is dictated by such factors as soil properties, initial and boundary condition at the soil surface landscape features, and agricultural management. Soil permeability vary spatially and temporally from a field scale to a large regional scale (Sun et. Al, 2003) and are influenced by both intrinsic (e.g. soil formation process, composition of parent rocks, soil organisms) and extrinsic (e.g. regional climate, vegetation, soil management practices, fertilization, etc.). Spatial variability causes difficulty in representing a soil with a deterministic or precisely defined set of characteristic of soil hydrological response. In the past, classical statistic has been widely used to access the variability of soil permeability (Biggar and Nielsen, 1976). Statistical variability involves parameter estimation such as the mean and variance.

Classical statistics assumes that observation in the field is random regardless of their location. But some show that variation to be correlated across space. Therefore classical statistical method may be inadequate for interpolation of spatially dependant variables, because they assume random variation and do not consider spatial correlation and relative location of samples. Thus geo-statistical procedure recognizes these difficult and provides tool to facilitate the examination of spatial and temporal correlation in data (Cromer, 1996). Recently, there has been increasing concern about how to estimate attributes of spatially varying soil properties (Sun et. Al, 2003). Therefore, spatial variability of soil hydraulic properties should be monitored and quantified.

1.3 Objectives

i. The objective of the study is to characterize spatial of permeability characteristics of soil under tropical climate in term of semi variogram parameter.
ii. To map the variation in soil hydraulic characteristics in the study area that is affected by several factors such as soil texture, soil moisture content, bulk density, surface porosity and other biological activity.
iii. To evaluate the effect of change in land use that affect on the variability of permeability characteristics in the study area.

1.4 Scope of study

The scope of study is to determine the inconsistency of permeability characteristics of soil hydraulic properties inside UTP campus area. The Falling Head Permeability Test of the soil sample is done to measure the permeability for every soil samples in different location around the campus area. The statistics and geo-statistic characterization of the data was performed and the Kriging method is used for mapping the contour mapping of the ensample area as the result of the spatial variability of the permeability.

CHAPTER 2: LITERATURE REVIEW

2.1 Permeability

Soil permeability characteristic is one of the key components of hydrology cycle. Permeability is the rate at which fluid can flow through the pores of a solid (Schlumberger, 2008).Wikipedia defined soil permeability as;

"...is a measure of the ability of a material to transmit fluids."

"...the ease with which water can move through pore spaces or fractures. It depends on the intrinsic permeability of the material and on the degree of saturation. Saturated hydraulic conductivity, describes water movement through saturated media."

MWDOCS define permeability as;

"The capability of soil or other geologic formations to transmit water."

The lasting forests define it as;

The readiness with which soil or rock allows water, air, or plant roots to penetrate or pass through. It is measured by the rate at which water can enter and move through soil in a given interval of time under standard conditions.

Permeability (hydraulic conductivity) is the quality of soil that enables water to move downward through the soil. Permeability rate is estimated from soil physical properties and is expressed in inches per hour. Permeability rates affect runoff, leaching, and decomposition rates of manures that are applied to or incorporated in the surface layer. Application and incorporation of manures improve soil surface intake and permeability; however, frequent applications at high rates can clog soil pores and reduce soil surface permeability and intake.

Manures applied to soils that have a permeability of less than 0.2 inch per hour should be incorporated (solids) or injected (liquids) into the soil, reducing potential surface water contamination from erosion and runoff. Reduced rate and multiple applications of liquid manure are recommended for soils that have a permeability of more than 2 inches per hour. Application of manure near the time of nutrient utilization of growing crops should achieve similar results. Reducing the rate of application and using split applications of manure solids on soils that have severe permeability limitations can reduce the potential for contamination of shallow aquifers. Soil texture is the most important factor for nutrient and moisture availability. It is also a key factor in soil aeration which is a limiting factor for many desert plants.

The book title 'Remediation technologies for soils and groundwater by Alok Bhandari' just explain about the intrinsic soil permeability of a soil is a measure of its ability to transmit fluids which determines the rate at which oxygen can be supplied.

The type of soil such as clay, sand or silt, its texture and structure is the important characteristic under this category. If soil has high permeability, rainwater will tend to accumulate on surface or flow across the surface if it is not level (Schlumberger, 2008). Permeability is a complex process that depend upon physical of the soil moisture content, previous wetting history, structural change and air entrapment (Delhomme, 1979)

Solutions are developed for the steady, partially drained, fluid pressure field that develops around a moving penetrometer. These include rigorous solution for a point volumetric dislocation moving in a saturated elastic soil and an approximate solution for a pseudo static, finite-volume, penetrometer moving in a nondilatant soil. These solutions provide a consistent framework for viewing the penetration process, and enable the nondimensional sounding indices of normalized tip resistance Q_t, friction factor F_r and pore pressure ratio B_q, to be straightforwardly linked to important material properties of the soil, most notably that of permeability, via a nondimensional permeability K_D. This factor K_D is inversely proportional to penetration rate, and is directly proportional to both permeability and vertical in situ effective stress. Simple relationships are developed to link these nondimensional sounding metrics, via KdD. Most notably, the resulting simple relationship $K_D=1/B_qQ_t$ enables soil permeability to be determined from peak fluid pressures recorded on-the-fly. Importantly, these parameterizations enable plots of B_q-Q_t, F_r-Q_t, and B_q-F_r to be contoured for K_D, and hence for permeability. These plots define the relative superiority of using B_q-Q_t data pairs over those for F_r-Q_t and B_q-F_r, in defining permeability. Similarly, the feasible ranges of permeability that may be recovered from peak pressure data are defined; permeability must be sufficiently high that penetration is not undrained, and sufficiently low that the resulting pressure response is not null (fully drained). These limits are a natural product of the analysis and represent permeability in the range 10^{-4}-10^{-7} m/s. The utility of these characterizations is confirmed with data from two locations where cone soundings are correlated with independently estimated permeability.

Soil-water characteristics curve (SWCC) is a fundamental constitutive relation for the explanation of the engineering behavior of unsaturated soil. The study of SWCC is helpful for reducing the time and cost of unsaturated soil testing for engineering purposes. Some properties of unsaturated soils, such as shear strength and permeability, can be predicted from it. After a brief introduction to osmotic technique and vapor phase method, the SWCCs of Shanghai soft soil have been obtained and some basic characteristics of the SWCCs have been analyzed. Coefficient of permeability is an important parameter for unsaturated soils, but the wide range in coefficient of permeability has been proven to be a major obstacle in analyzing seepage problems. Childs and Collis-George proposed a model for predicting the coefficient of permeability based on the random variation of pore size. It was improved several times and proved to be effective. Based on this model, the relative coefficients of permeability of Shanghai soft soil are predicted from the soil-water characteristic curves. Results show that unsaturated permeability of Shanghai soft soil changes nonlinearly with suction.

Soil permeability is the property of the soil pore system that allows fluid to flow. It is generally the pore sizes and their connectivity that determines whether a soil has high or low permeability. Water will flow easily through soil with large pores with good connectivity between them. Small pores with the same degree of connectivity would have lower permeability, because water would flow through the soil more slowly. It is possible to have zero permeability (no flow) in a high porosity soil if the pores are isolated (not connected). It is also to have zero permeability if the pores are very small, such as in clay. The Falling Head test is given below (Geocitg, 2010):

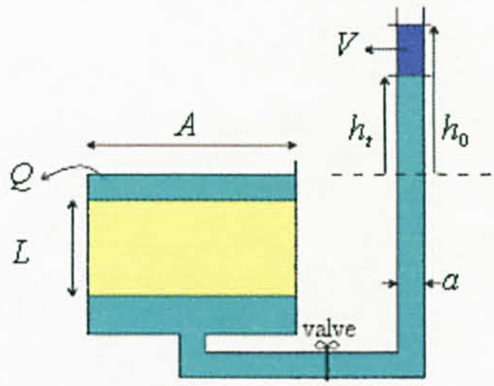


Figure 2.1: Falling head permeability

A = Cross-section of soil sample

a = Cross-section of tube

L = Height of soil sample

V = Change of volume between time t_0 and time t

h_0 = Height of water table at time t_0

h_t = Height of water table at time t

The water table h in the tube at the left side of the soil sample varies in time, so we write $h\ (t)$. The initial water table is h_0. V is the volume of water that leaves the tube during Δt, while the water table drops from h_0 to $h\ (t_0+\Delta t)$. Thus:

$$V = a\Delta h \tag{2.1}$$

where $\Delta h = h_0 - h(t_0+\Delta t)$. Of course, the same volume of water flows through the sand column, which is $Q\Delta t$. Thus, the flow of water Q through the soil is $(Q=V/\Delta t)$:

$$Q = a\frac{\Delta h}{\Delta t} \tag{2.2}$$

According to Darcy's law we can write:

$$Q = -AK\frac{h}{L} \tag{2.3}$$

When we combine eqs (1) and (2) we find:

$$\frac{\Delta h}{h} = -\frac{AK}{La}\Delta t \tag{2.4}$$

Integration gives:

$$h(t) = h_0 \exp\left(-\frac{AKt}{La}\right) \tag{2.5}$$

This equation can be written as follows:

$$K = -\frac{La}{At}\ln\left(\frac{h(t)}{h_0}\right) \tag{2.6}$$

The falling head test can be used to determine the permeability *K*.

2.2 Spatial variability of soil hydraulic

It can say that almost all spatial variability studies of permeability rates have been conducted on agricultural soil (Sisson & Wierenga, 1981; Vieira et. al., 1981). Recent studies (Achouri & Gifford, 1984) looked at spatial and temporal variability of soil hydraulics on a seeded rangeland. Characterization of spatial structure of soil hydraulic properties is vital for analysis in:

I. Determining the optimum size of spatial grids for distributed parameter hydrological models (Anctil et al., 2002)
II. Estimating point of spatially averaged values of soil properties using Kriging method (Bardossy and Lehmann, 1998)

The spatial distribution of soil pores effect the permeability of water into soil, lateral soil moisture redistribution as well as determines rainfall runoff responses in many catchments (Anctil et al., 2002). Thus, the variation of permeability characteristic in soil hydraulic properties should be monitored.

2.3 Normal Statistics

The normal distribution has two parameters, the mean mu and the standard deviation sigma. Once the parameters are known, the distribution is completely specified. It can be shown, although we will not do so (yet) that a good guess or estimate for mu is the mean of the observed values. An estimate for sigma is the standard deviation. Although the standard deviation is a positive number, the mean can assume any value.

The distribution is symmetrical with mean, mode, and median all equal at mu. It is interesting to note that the exact specification of the figure shown here was taken from the German 10 DM banknote. The mean equals three, and the standard deviation equals one in this example. On the back of the banknote is a portrait of Gauss (Stattucino, 2010).

A statistic (singular) is a single measure of some attribute of a sample (eg its arithmetic mean value). It is calculated by applying a function (statistical algorithm) to the values of the items comprising the sample which are known together as a set of data.

More formally, statistical theory defines a statistic as a function of a sample where the function itself is independent of the sample's distribution: the term is used both for the function and for the value of the function on a given sample.

A statistic is distinct from an statistical parameter, which is not computable because often the population is much too large to examine and measure all its items. However a statistic, when used to estimate a population parameter, is called an estimator. For instance, the *sample mean* is a statistic which estimates the *population mean*, which is a parameter.

In calculating the arithmetic mean of a sample, for example, the algorithm works by summing all the data values observed in the sample then divides this sum by the number of data items. This single measure, the mean of the sample, is called a statistic and its value is frequently used as an estimate of the mean value of all items comprising the population from which the sample is drawn. The population mean is also a single measure however it is not called a statistic; instead it is called a population parameter (Wikipedia, 2010).

Other examples of statistics include

- Sample mean discussed in the example above and sample median
- Sample variance and sample standard deviation
- Order statistics, including sample maximum and minimum

2.4 Geostatistics

Geostatistics is a branch of statistics focusing on spatiotemporal datasets. Developed originally to predict probable distributions for mining operations, it is currently applied in diverse disciplines including petroleum geology, hydrogeology, hydrology, meteorology, oceanography, geochemistry, geometallurgy, geography, forestry, environmental control, landscape ecology, soil science, and agriculture (esp. in precision farming). Geostatistics is applied in varied branches of geography, particularly those involving the spread of disease (epidemiology), the practice of commerce and military planning (logistics), and the development of efficient spatial networks. Geostatistics are incorporated in tools such as geographic information systems (GIS) and digital elevation models (Wikipedia, 2009).

G. Matheron talks about geostatistic as
"...in, their most general acceptation, are concerned with the study of the distribution in space of useful values or mining engineers and geologist..."

2.5 Kriging Method

Kriging is a group of geostatistical techniques to interpolate the value of a random field (e.g., the elevation, *z*, of the landscape as a function of the geographic location) at an unobserved location from observations of its value at nearby locations.

Kriging belongs to the family of linear least squares estimation algorithms. The aim of kriging is to estimate the value of an unknown real-valued function, *f*, at a point, x^*, given the values of the function at some other points, $x_1, \ldots, x_n$. A kriging estimator is said to be *linear* because the predicted value $\hat{f}(x^*)$is a linear combination that may be written as

$$\hat{f}(x^*) = \sum_{i=1}^{n} \lambda_i(x^*) f(x_i)$$

(2.7)

The weights λ_i are solutions of a system of linear equations which is obtained by assuming that *f* is a sample-path of a *random process* $F(x)$, and that the error of prediction

$$\varepsilon(x) = F(x) - \sum_{i=1}^{n} \lambda_i(x) F(x_i)$$

(2.8)

is to be minimized in some sense. For instance, the so-called *simple kriging* assumption is that the mean and the covariance of $F(x)$ is known and then, the kriging predictor is the one that minimizes the variance of the prediction error.

From the geological point of view, the practice of kriging is based on assuming continued mineralization between measured values. Assuming prior knowledge encapsulates how minerals co-occur as a function of space. Then, given an ordered set of measured grades, interpolation by kriging predicts mineral concentrations at unobserved points (Wikipedia, 2010).

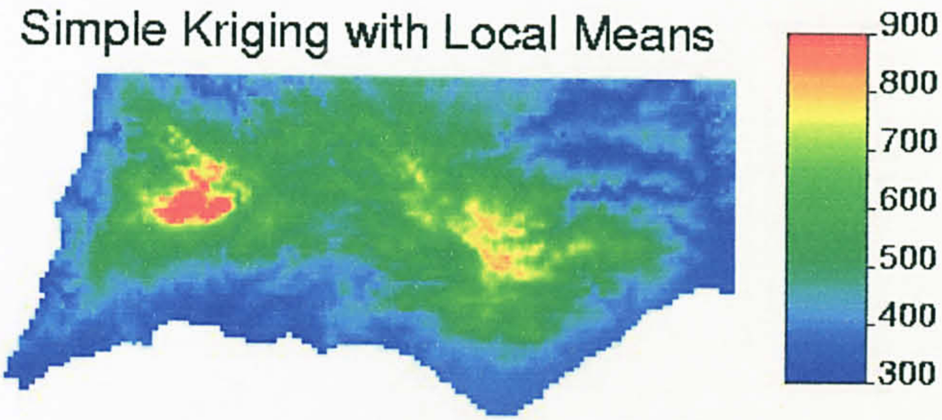


Figure 2.2: Simple Kriging contour

Kriging is an optimal prediction method designed for geophysical variables with a continuous distribution. The variable values are somewhat random but their variation is not described by any geometric function. Kriging interpolates an elevation value for each output raster cell by calculating a weighted average of the elevations at nearby vector or database points or TIN nodes. Closer points / nodes are weighted more heavily than more distant ones in the calculation. The Kriging method analyzes the statistical variation in values over different distances and in different directions to determine the shape and size of the point selection area as well as the set of weighting factors that will produce the minimum error in the elevation estimate.

CHAPTER 3: METHODOLOGY

3.1 Research Methodology

In studying the spatial variability of the permeability, soil hydraulic properties (permeability) within UTP campus area will be examined. Three steps involved which include:

1. Preparation of the geo-grid for sampling of at least 50 different points. Determine the coordinates of the location the soil sample will taken by GPS.
2. Conducting the Falling Head Permeability Test to determine the permeability value for a different soil sample taken from the different locations in UTP campus area.
3. Digitizing Software use to digitize the boundary map of the study area. Computer analysis of the soil permeability data to examine the spatial variability of the permeability, to quantity the spatial correlation in the data in terms of the semivariogram parameters, and to prepare spatial distribution maps of the soil permeability by using the statistical and geo-statistical method from the GS+ and Surfer software. Use Kriging method for interpolation of the unsample locations.

3.2 Project Work

Figure 3.1: UTP map

The study area was conducted in the University Technology of PETRONAS (UTP) campus area as shown in the figure above, located in Tronoh. The study area is in the west part of Perak. It lies on latitude 4° 23.01' 30'' N and 100° 58' 41'' E. it is about 19 kilometers from Batu Gajah town. The campus is subdivided into two regions which are disturbed which consist of academic block, administration blocks, hostel and all the infrastructures. Another region is undisturbed area where all the tree and forest are remaining untouchable.

3.2.1 Geo-grid sampling location

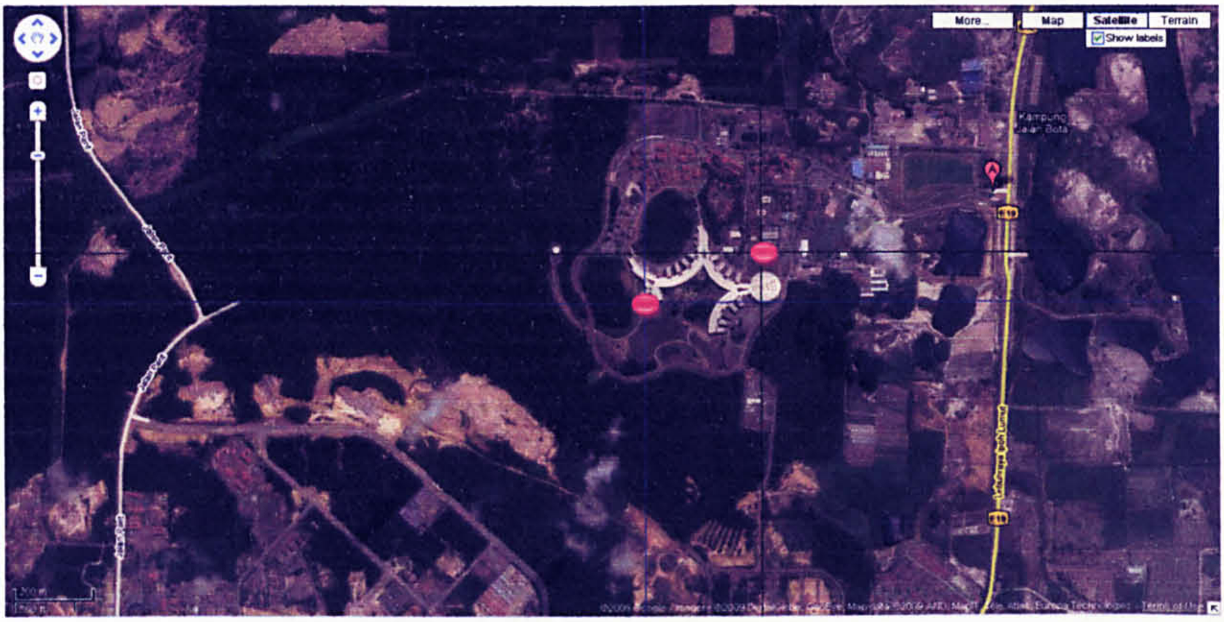


Figure 3.2: Location for reference point

The GPS device as shown in above figure has been installed in 2 locations. This will act as the reference point to determine the other longitude and latitude points. In setting the device, the procedure below:

1. Switch on the device by press the 'on' button
2. Prepare the device (wait for a while)
3. Set the device to show the longitude and latitude of the current location.
4. Place the device onto the desire location and leave it for 2 to 3 minutes.
5. After that, read the reading shown in the device and record the measurement.
6. Press the 'off' button to switch off the device.

Figure 3.3: The GPS device

Figure 3.4: Place device at the location

Figure 3.5: Record reading from GPS device

The location for the GPS is shown in above map (Figure 3.2).

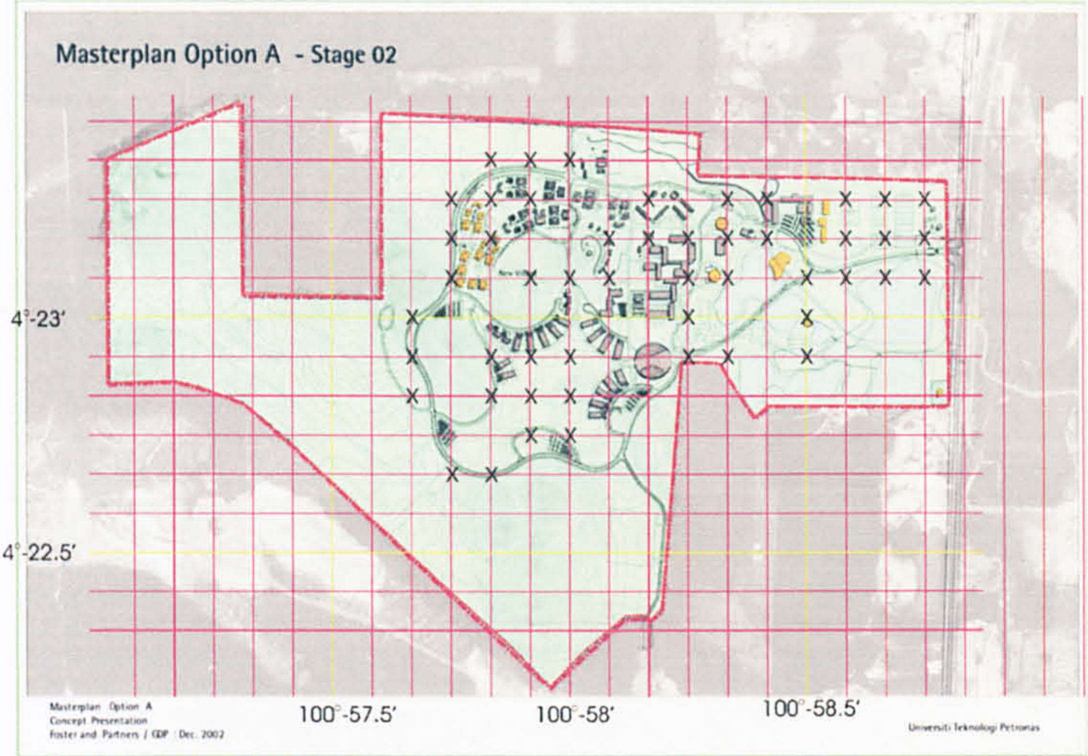


Figure 3.6: The geo-grid of 50 sample location

3.2.2 Falling-head method

Soil sample was tested for the permeability test shown in figure below to determine the coefficient of permeability by using the Falling Head Method.

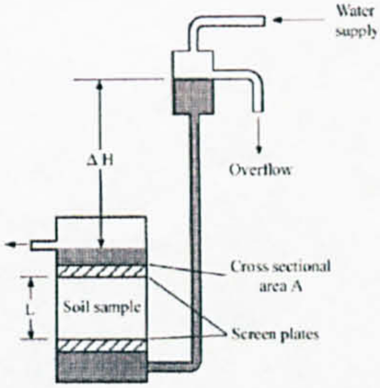


Figure 3.7: Falling head apparatus

The falling-head method is very similar to the constant head methods in its initial setup; however, the advantage to the falling-head method is that can be used for both fine-grained and coarse-grained soils. The soil sample is first saturated under a specific head condition. The water is then allowed to flow through the soil without maintaining a constant pressure head.

It should be noted that this method of determining the coefficient of permeability is well adapted for long duration tests on fine grained soils where a relatively small volume of water will flow through the sample. For tests of long duration, provisions can be made to control evaporation from the standpipe by using a controlled-humidity room, or by placing a partially inflated rubber balloon over the standpipe end.

$$K = \frac{La}{At}\log\left(\frac{h_1}{h_2}\right) \qquad (3.1)$$

A = Cross-section of soil sample

a = Cross-section of tube

L = Height of soil sample

V = Change of volume between time t_0 and time t

h1 = Height of water table at time t

h2 = Height of water table at time t_0

Falling Head Permeability Procedure

The procedure for the Falling Head Method as below:

1. Preparation of the sample by fills the mold with soil sample and compact it by the Proctor Hammer (21 blows).
2. Place the filter paper or fine wore mesh on the top of the soil specimen and fix the perforated base plate on it.

3. Turn the assembly upside down and remove the compaction plate. Insert the sealing gasket and place the top perforated plate on the top of soil specimen. And fix the top cap.
4. Saturated it for 24 hours. Deaired water is preferred.
5. Assemble the permeameter in the bottom tank and fill the tank with water.
6. Inlet nozzle of the mold is connected to the stand pipe. Allow some water to flow until steady flow is obtained.
7. Note down the time interval 't' for a fall head in the stand pipe 'h'.
8. Repeat step 5 three times to determine 't' for the same 'h'.
9. Calculate the permeability of soil sample by below equation:

$$K = \frac{La}{At}\log\left(\frac{h_1}{h_2}\right) \tag{3.2}$$

3.2.3 Statistical analysis

To analyze the results of permeability test measurements on soil permeability characteristics the statistical analysis will be used. The analyses include the process of collecting and analyzing data and then summarizing the data into a numerical form. The measurement of all 50 samples will show variation in each point as the soil permeability characteristics of each point are different with another making it difficult to identify the parameters. The general statistical parameters that will calculate include the maximum, minimum, mean, standard deviation and coefficient of variation (CV) for each soil permeability parameters.

3.2.4 Analysis using Semivariogram Modeling

In spatial statistics the okapi (theoretical) variogram $2\gamma(x,y)$ is a function describing the degree of spatial dependence of a spatial random field or stochastic process $Z(x)$. It is defined as the expected squared increment of the values between locations x and y (Wackernagel 2003).

All semivariogram parameters in this study are computed using the GS+ software (Gamma Design Software, Plainwell, MI, USA) and Surfer software. Semi variance is a measure of the degree of spatial dependence between samples. The Semi variance was estimated for the permeability data. The Semi variance is defined as (Goovaerts, 1997):

$$\hat{\gamma}(h) = \frac{1}{2} \cdot \frac{1}{n(h)} \sum_{i=1}^{n(h)} (z(x_i + h) - z(x_i))^2 \tag{3.3}$$

Where z is a datum at a particular location, h is the distance between ordered data or known as the lag, and n (h) is the number of paired data at a distance of h. The Semi variance is half the variance of the increments $z\ (x_i + h) - z(x_i)$, but the whole variance of z-values at given separation distance h (Bachmaier and Backes, 2008).

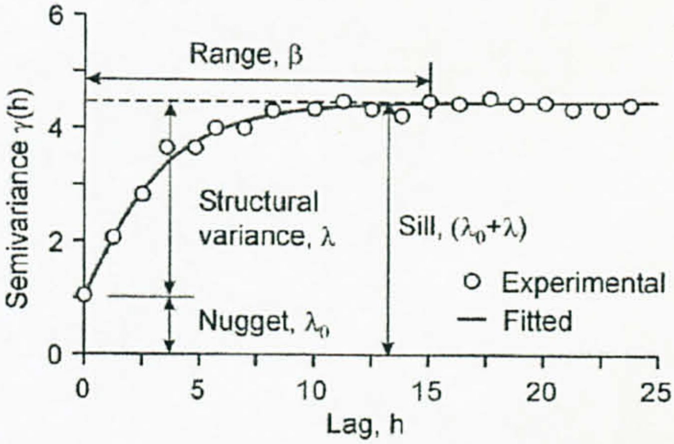
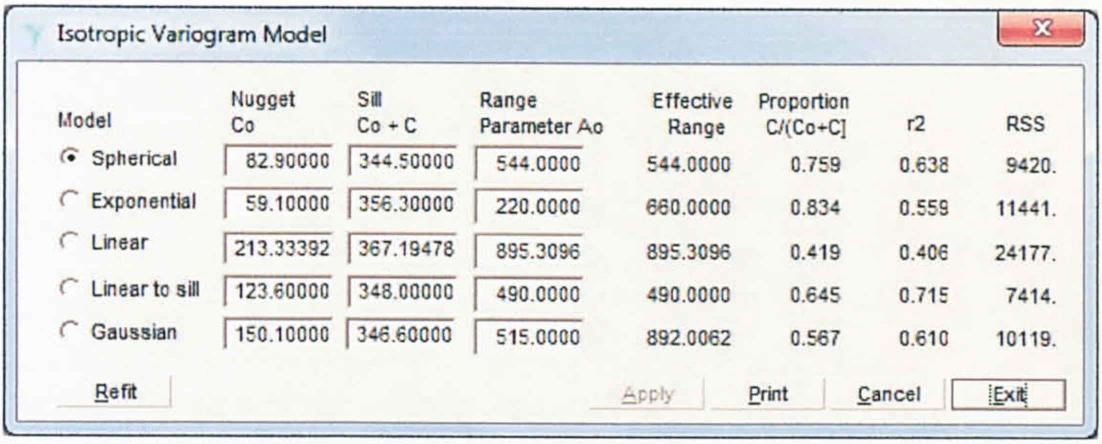


Figure 3.8: Schematic diagram of a semivariogram and its parameters

The magnitude of the semi variance between points depends on the distance between the points. A smaller distance gives a smaller semi variances and a larger distance gives a larger semi variances.

A property is called spatially dependent or auto correlated if the probability of similar data values is higher for neighboring sample points than for points far from each other (Warrick et al., 1986). Thus $z(x_i)$ correlates to $z(x_i + h)$ by h being the lag between these two data. The correlation between $z(x_i)$ and $z(x_i + h\ )$ expresses the spatial structure of a variable of interest (Isaaks and Srivastava, 1989). Figure 3.8 illustrates an experimental and fitted semivariogram with parameters. The Semi variance rises with the increasing lag then levels off.

Five different models (Figure 3.9) were examined to fit the Semi variance data. These include the spherical, exponential, linear, linear-to-sill and Gaussian model. The optimal models were determined by examining the fit of the model to the semivariogram as judged by the coefficient of determination (r^2) and RSS (residual sums of squares) (Wikipedia, 2009).


Isotropic Variogram Model

Model	Nugget Co	Sill Co + C	Range Parameter Ao	Effective Range	Proportion C/(Co+C]	r2	RSS
Spherical	82.90000	344.50000	544.0000	544.0000	0.759	0.638	9420.
Exponential	59.10000	356.30000	220.0000	660.0000	0.834	0.559	11441.
Linear	213.33392	367.19478	895.3096	895.3096	0.419	0.406	24177.
Linear to sill	123.60000	348.00000	490.0000	490.0000	0.645	0.715	7414.
Gaussian	150.10000	346.60000	515.0000	892.0062	0.567	0.610	10119.

Refit Apply Print Cancel Exit

Figure 3.9: Isotropic Variogram Model

The model above shows the nugget, sill, range parameter, effective range, proportion, r^2 and also RSS for every model.

Proportion of Spatial Structure or C/(Co+C) provides a measure of the proportion of sample variance (Co+C) that is explained by spatially structured variance C.

Regression Coefficient or r^2 provides an indication of how well the model fits the variogram data but this value is not as sensitive or robust as the RSS value below for best-fit calculations.

RSS or Residual Sums of Squares provides an exact measure of how well the model fits the variogram data; the lower the reduced sums of squares, the better the model fits. GS+ uses RSS to choose parameters for each of the variogram models by determining the combination of parameter values that minimizes RSS for any given model. In statistics, the residual sum of squares (RSS) is the sum of squares of residuals. It is a measure of the discrepancy between the data and an estimation model. A small RSS indicates a tight fit of the model to the data.

3.2.5 Analysis using the Contour Map (Kriging Analysis)

Kriging is the common method for spatial interpolation in the Earth Sciences. It is a clever, constrained, parametric regressor that is sometimes called nonparametric. Kriging is a group of geostatistical techniques to interpolate the value of a random field (e.g., the elevation, z, of the landscape as a function of the geographic location) at an unobserved location from observations of its value at nearby locations. Kriging belongs to the family of linear least squares estimation algorithms.

Yakowitz and Szidarovsky (1985) developed theoretical results to establish the consistency and convergence properties of Kriging. For Kriging to work, they showed that proper variogram selection was critical. They formalized a Nadaraya Watson kernel regression estimator for spatial regression, established its consistency and convergence rates, utility for estimating functional (e.g., integrals or derivatives of the surface), and developed a NN estimator of the local mean square error of estimation.

3.2.6 Tool and Equipment

Software

1. CorelDRAW 9
2. GS+
3. Surfer
4. Digitizing
5. Microsoft Excel

Hardware

1. Scope and trowel
2. Falling Head apparatus
3. Plastic bags
4. GPS device
5. Proctor hammer
6. Extruder Machine

3.2.7 Gantt chart and Milestone of Project

Gantt chart and Milestone of Project is attached in the appendices behind (refer appendices 2)

3.2.8 Project flow in the appendices

Project flow in the appendices is attached in the appendices behind (refer appendices 1)

CHAPTER 4: RESULT AND DISCUSSION

4.1 The geo-grid sampling method

The geo-grid sampling method was used for this study on the premise that grid-sampling reduces the possibility of uneven samples. First, take the map of UTP from Google earth. The map consists of all the building, road and pavement, trees, contours and also boundaries of UTP. Then the campus area from the map is divided by a number of regular geo-grids by using the CorelDraw 9 software. There will be two reference points that taken by GPS as the reference to make the geo-grid as shown in map before. One of the reference point lies on latitude of 4° 23' 00'' N and 100° 58' 10''E which is near the Chancellor hall while the point near the Block 13 lies on latitude 4° 22'52'' N and 100° 57' 51'' E. The location for each soil sample collection points will be marked based on the intersection of grid lines. 50 points will be chosen from the generated campus map for soil sample testing.

Soil sample will were collected at each-grid node. The sampling location which fell on paved area or on building or where the sampling location was inaccessible was omitted. If sample location fell at the corner of the building, the samples were collected from the adjacent ground.

During field sampling, the grid nodes were located by the GPS (Global Positioning System). Fifty soil samples were collected around the UTP campus. The samples then sealed in plastic bags and bring to the laboratory for analysis.

To start the progress for the project, 1st the map of UTP must be add grid line so that the location of the sample that will collect will be designated. To draw the grid line above the picture, the software called Adobe Photoshop was used. This software has so many tools that can make sure the accuracy of the grid line was acceptable. By referring to the reference point that been take before, the grade line can be draw. From the reference point, the degree of the location can be determined by doing some calculation with the data taken from the GPS. By calculating the distance between 2 reference points, the grid line can be made. The gridline spacing was depend on the how many point that the y-axis grid intersect with x-axis grid, and for this project it used about 5'' interval for every y and x lines. And for this project, the minimum number of point of intersect was about 50, so below are the result of the map that been draw grid line.

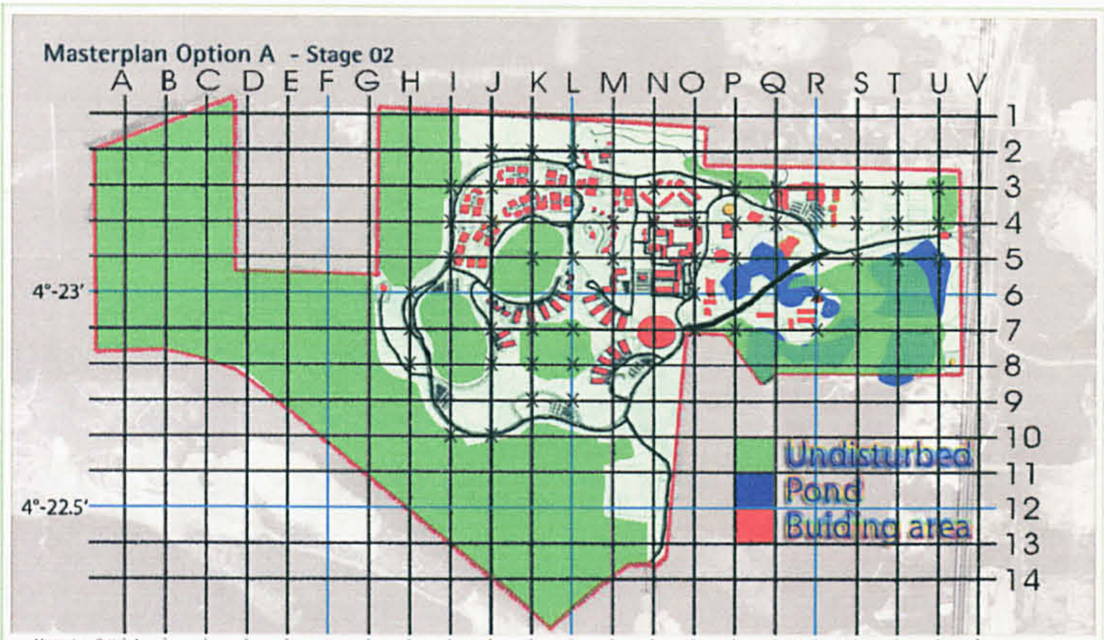


Figure 4.1: Finished grid line for UTP map with sample location

From the image above, the point for the sample can be decided. The point must be collection of the disturbed area and undisturbed area that will show the variety of result. On the above map, there are already some point that been chosen to take sample, it been mark by 'X'.

By using Corel Draw software, the building or any other object can be draw as vector drawing so that it can be used for future during the analysis for spatial of permeability. This vector drawing can be larger from its original size. So the larger it can get the better accuracy of the result.

After drawing the gridline done, the map will be import to the software named Digitizer. This software can show the position the latitude and longitude of the map that been define by adding the value of the reference points. This program, will show the latitude and longitude of any the point in the map. It makes the work easy and no calculation needed to get this read afterward.

In the next phase of study, the author will proceed into the Falling Head Permeability Test and 50 point was to be done.

4.2 Falling Head Permeability Test

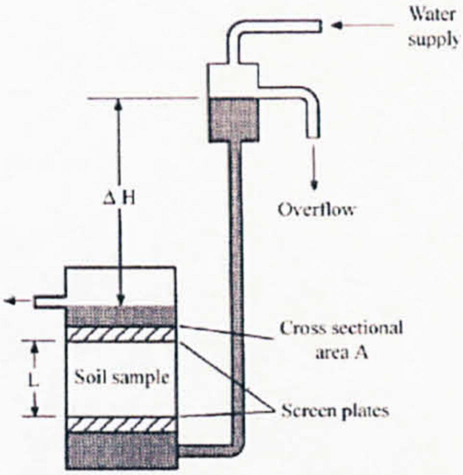


Figure 4.2: Falling head apparatus

Result for the first sample, the result as below;

Diameter standpipe	=	4.6mm
Diameter of sample	=	100mm
Time	=	514s
Height at t_0	=	90mm
Height at t	=	30mm
Area of standpipe, a	=	$16.62mm^2$
Area of sample, A	=	$7853.98mm^2$
K	=	$(aL/At) \log (h_0/h_t) = 9.52 \times 10^{-4}$mm/s

After getting all the result of permeability, Digitizing software is used to digitize the map. The semivariogram parameter is established, and then it is possible to examine spatial variability. The Kriging method is used for spatial distribution of soil properties for unsample location. The proposed project is expected to contribute to the understanding and characterization of small scale spatial variability nature of permeability characteristics of soil in UTP campus area.

The measurement for all the 50 sample result have been attach behind (Appendix Table 2) in the form of Excel Spreadsheet. Then, after all the result of the permeability is got, the statistical analysis is done to the permeability data.

4.3 Statistical analysis

The normal statistics summary of the soil permeability obtained from 50 samples (Refer Appendix: Table 2). The indicator of variability is the coefficient of variation (CV). The low CV of the soil permeability is expected because the permeability variability is considered low.

Mean: The average of a numerical set. It is found by dividing the sum of a set of numbers by the number of members in the group.

Median: The value of a numerical set that equally divides the number of values that is larger and smaller. For example, in a set containing nine numbers, the median would be the fifth number.

Standard deviation: A number representing the degree of variation within a numerical set.
Coefficient of Variation: normalized measure of dispersion of a probability of distribution.

Table 1: Statistical Analysis

Number of numeric cells	50
Sum	344.4518
Average	6.889037
Standard Deviation	16.63238
Minimum	0.5501976
Maximum	84.3025
Median	2.192212839
Coefficient of Variation	2.414325834
Variance	276.6362373

4.4 Geostatistical Analysis

Isotropic variogram model is whenever the spatial correlations depend only on the distance (and not on the direction) of separation, while the spatial correlations are stronger or more persistent in some directions than others, the spatial correlation pattern is said to be anisotropic. (Math UMT, 2008).

Range or A_0 is the distance over which spatial dependence is apparent for the permeability data. Effective Range is separation distance at which points in the modeled domain are no longer spatially correlated. From the result above, it shows that spherical model gives the data for range parameter and effective range parameter with a value that is the same.

Proportion of Spatial Structure or C/(Co+C) or also known as nugget-to-sill ratio provides a measure of the proportion of sample variance (Co+C) that is explained by spatially structured variance C. It also indicate that the spatial dependency of the data. Higher the value, stronger the dependency of data. Result shows that data proportion is higher for the spherical model.

Regression Coefficient or r^2 provides an indication of how well the model fits the variogram data. The r^2 is indicates by the higher the data of r^2, the better the model fits the data. But this value is not as sensitive or robust as the RSS value below for best-fit calculations.

RSS or Residual Sums of Squares provides an exact measure of how well the model fits the variogram data; the lower the residual sums of squares, the better the model fits. GS+ uses RSS to choose parameters for each of the variogram models by determining the combination of parameter values that minimizes RSS for any given model. It is a measure of the discrepancy between the data and an estimation model. A small RSS indicates a tight fit of the model to the data. From the result, it shows that the RSS for spherical is small.

After combining the parameter values that minimize the RSS value, it is shows that the spherical model is the best model that fitted the permeability data and that is why GS+ use it as the plotted model.

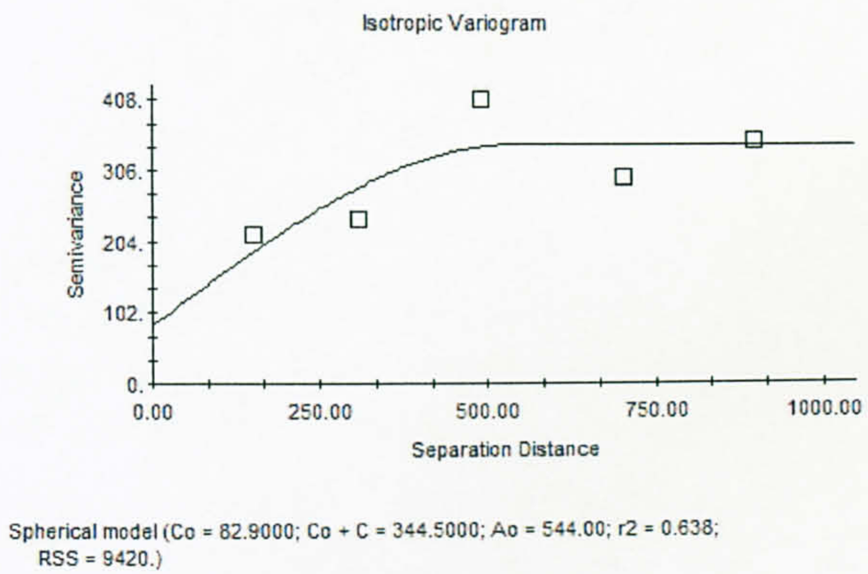


Figure 4.3: Empirical semivariogram and best-fitted semivariogram of soil permeability

The Active Lag Distance specifies the range over which Semi variance will be calculated .The range is considered as the distance beyond which the observations are not spatially dependent or separation distance over which sample locations are autocorrelated, i.e. over which there is spatial dependence among sample locations. In the study area, the permeability showed the range that is 544 m. Over than this range, the sample is consider as not autocorrelated.

The nugget-to-sill ratio gives and indication of the spatial dependency of the data. A variable is considered to have a strong dependency if the ratio is less than 25%, and a moderate spatial dependency if ratio is 25% - 75% and weak dependency if greater than 75% (Goderya et al., 1996). The nugget-to-sill ratio for the permeability examined in the study is less than 25%. So the data is considered having a strong spatial dependency.

$$\frac{82.9}{344.5} \times 100\% = 24.06\% \qquad (4.1)$$

The nugget is measure of all unaccounted spatial variability at distance smaller than the smallest lag (83 m in this study) while the structural variance accounts for variation due to spatial autocorrelation. The small nugget for soil permeability suggest that less variation existed for these two soil properties at distances shorter than the smallest lag.

4.5 Mapping of the Permeability Distribution

The next step is to map of the permeability distribution in UTP campus area to see the spatial distribution. But for the mapping purposes, the data of the longitude and latitude is calculated in degree. Data in degree is also taken from the GPS where in the GPS it will show degree, the minutes and second, then calculation been made to convert it to degree. The mapping figure will have the latitude and longitude in degree Northing and Easting value. The result of the mapping is shown in Figure 4.4.

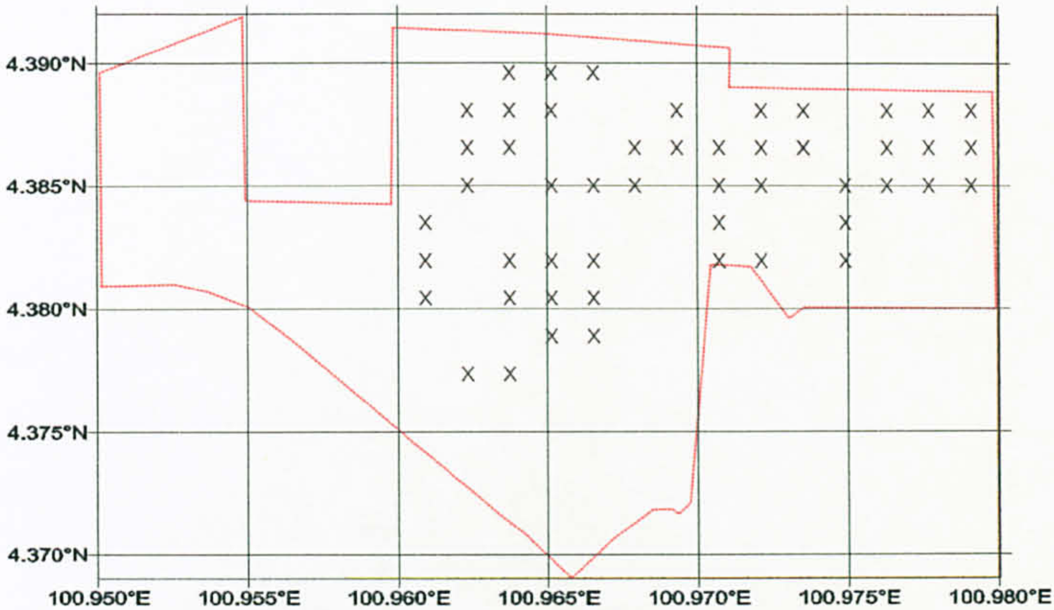


Figure 4.4: The digitize map of the boundary and sampling location. By Digitize and Surfer Software.

4.6 Kriging Spatial Soil Permeability

The spatial distribution of soil permeability for unsample locations in the study area was obtained from interpolation between sampled locations by the method of Kriging (Figure 4.5). Figure 4.5 below illustrates the spatial distribution of soil permeability over the study area. This map of spatial distribution of soil permeability in conjunction with the site map (Figure 4.1) now allows examining the closeness of association between variation in soil permeability and topographic condition.

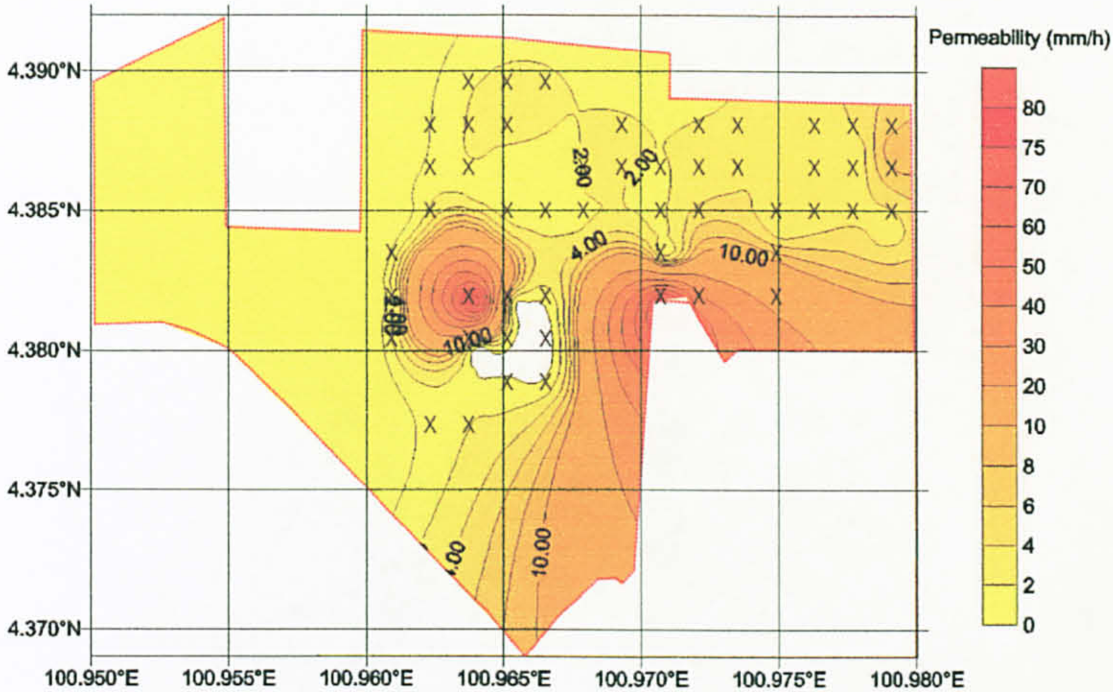


Figure 4.5: Spatial distribution of soil permeability in UTP area

Figure 4.5 shows that higher permeability appears to be related with lake while lower permeability appears to be related with the forest and near building area. Thus, it is reasonable to infer that the spatial variability is induced partly by these topographic features present in the study area.

4.7 Variation of soil properties on land use conditions

Statistical and geostatistical characterization of the soil permeability provide very strong evidence to the existence of the influence from intrinsic or extrinsic factors on the spatial variability of soil permeability. Thus, the effect of land use changes was examined. To examine this, the study area is divided by 2 zones which is disturbed and undisturbed area (refer Figure 4.1).

The disturbed zone is the zone with the forest clearance, building construction and ground alteration took place. Undisturbed area is where the ground is in its original condition such as the forest area. The mean of these two zones is investigated and compared as shown in Figure 4.6.

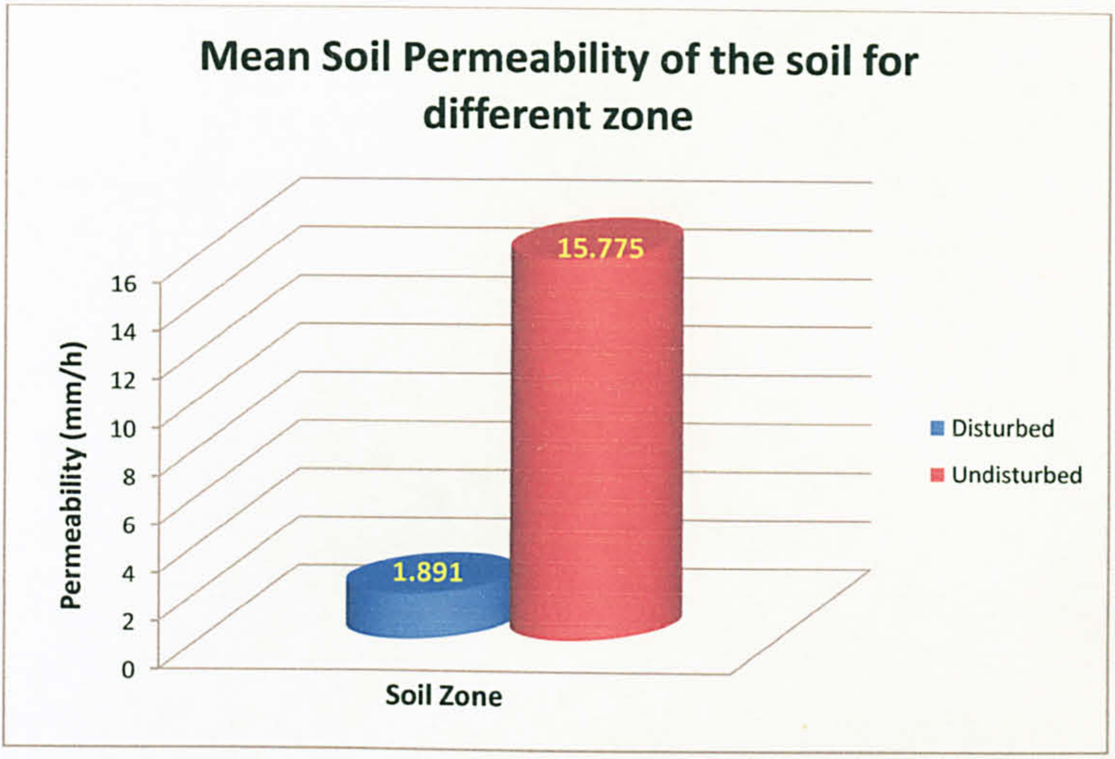


Figure 4.6: Effect of land use patterns on soil permeability.

Figure 4.6 indicates that the mean soil permeability is higher in the undisturbed zone compared to the disturbed area. The relatively lower permeability in the disturbed zone could be attributed to significant alteration of the soil either by compaction induced by the construction of the building or the human activities. Compaction can reduce the size and number of pores in the soil. Higher pores in the soil contributed to the higher permeability in the undisturbed zone because it is not subjected to the compaction like in the disturbed zone and also higher organic contents in soil which create pores and enhance the permeability of the soil (Wikipedia, 2009). As a result, the mean permeability in undisturbed soil zone is higher compared to the disturbed soil.

Thus, it shows that the differences of soil permeability between the disturbed and undisturbed zone is basically due to consequence of disturbances cause by the soil alteration for construction and also land clearance. It also shows that the variability appears due to the consequence of the land use conditions.

Soils that have lot of pores are very dangerous because it not stable due to the existing of the empty space in it. This can contribute to the landslide if it has enough force to make it move. Luckily the soils that have lot pores in UTP are safe because it not have any loading above it, plus it located near the pond area.

CHAPTER 5: ECONOMICAL BENEFIT

5.1 Cost of the project

This project has been done in University Technology PETRONAS. The cost for this project is very low and can be negligible since everything can be taken from Civil Department Laboratory (Geotechnical Laboratory). The tools for this project have been borrowed from the laboratory which is no cost involve. The soil sample only taken from UTP campus area which was free and water from the project also can be taken from tap water in laboratory.

5.2 Economics Value

The economics value for this project is this project can be done at any place. Since the cost for this project is very low cost and can be negligible, this experiment can be done at any site and it would not burden any client.

From this project, some engineering problems where soil permeability may play quite prominent role are:

1. Quantity of leakage through and under dams
2. Rate of consolidation and related settlement
3. Infiltration into and dewatering of deep excavation
4. Stability of slope, embankment, hydrostatic uplift evaluation
5. Seepage velocity through the soil may create erosion via transportation of fine-grained particles.

So by having this project, these problems could be reducing. Thus these contribute to economic value.

CHAPTER 6: CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The author concludes that the soil properties are varying spatially and both are influenced by the intrinsic and extrinsic factors. The spatial variability causes difficulty in representing a soil with a deterministic or precisely defined set of characteristics and precludes characterization of soil hydrological response. Therefore the spatial variability of soil properties should be monitored and quantified.

In the past, classical statistics is used widely to access the variability of soil properties (e.g Biggar and Nielsen, 1976). This proposed study will allow understanding and characterization of small scale spatial variability nature of permeability characteristics in University Technology of PETRONAS (UTP) campus area with a statistic and geostatistic method.

The geostatistic application in conjunction with the normal statistic analysis in evaluate the spatial variability of soil permeability revealed that certain aspects that not captured by normal statistic. By using geostatistic, it can indicate distance of where the correlated data occurred, the variability of the data and also the degree of the spatial dependency.

Besides, it also can allows mapping of the spatial distribution and the normal statistics will helped in identifying causes of the variability in the soil permeability. Others, even the semivariogram shows the consistent result, however the relatively low r^2 (0.638) show poor fit to data. This is because in the fact that the number of the sample is not enough for that extend of area studied.

This study will find out and characterize spatial structure of permeability characteristics of soil under tropical climate in terms of semivariogram parameters. By using geo statistical approaches the characterization of the spatial variability and scale dependence of permeability characteristics is performed.

The significant variation of soil permeability exists in the area of studied are shown in the result. Larger range and the lower sill indicates that the soil permeability are spatially dependent over long distance (large range) and the variability is low (indicates by low sill). Land disturbance and land topographic conditions donate to the variability of soil permeability.

6.2 Recommendation

Author suggests to have more narrowly spaced sampling data taken in order to make it relative to the area studied. For next time, more samples are taken so that it can combine with the past project that will make the result more accurate, also the study is expanding and continues for a lot of other applications in geotechnical studies, not only focusing in the farming practices.

The author also want to suggest that the apparatus in laboratory must be maintain and sustain the number and it condition so that in the future the apparatus are ready to use. During author time doing this project, there are some apparatus for Constant Falling Head Permeability test not available such as mould and the author need to fabricate it another one to make the progress of laboratory analysis fast.

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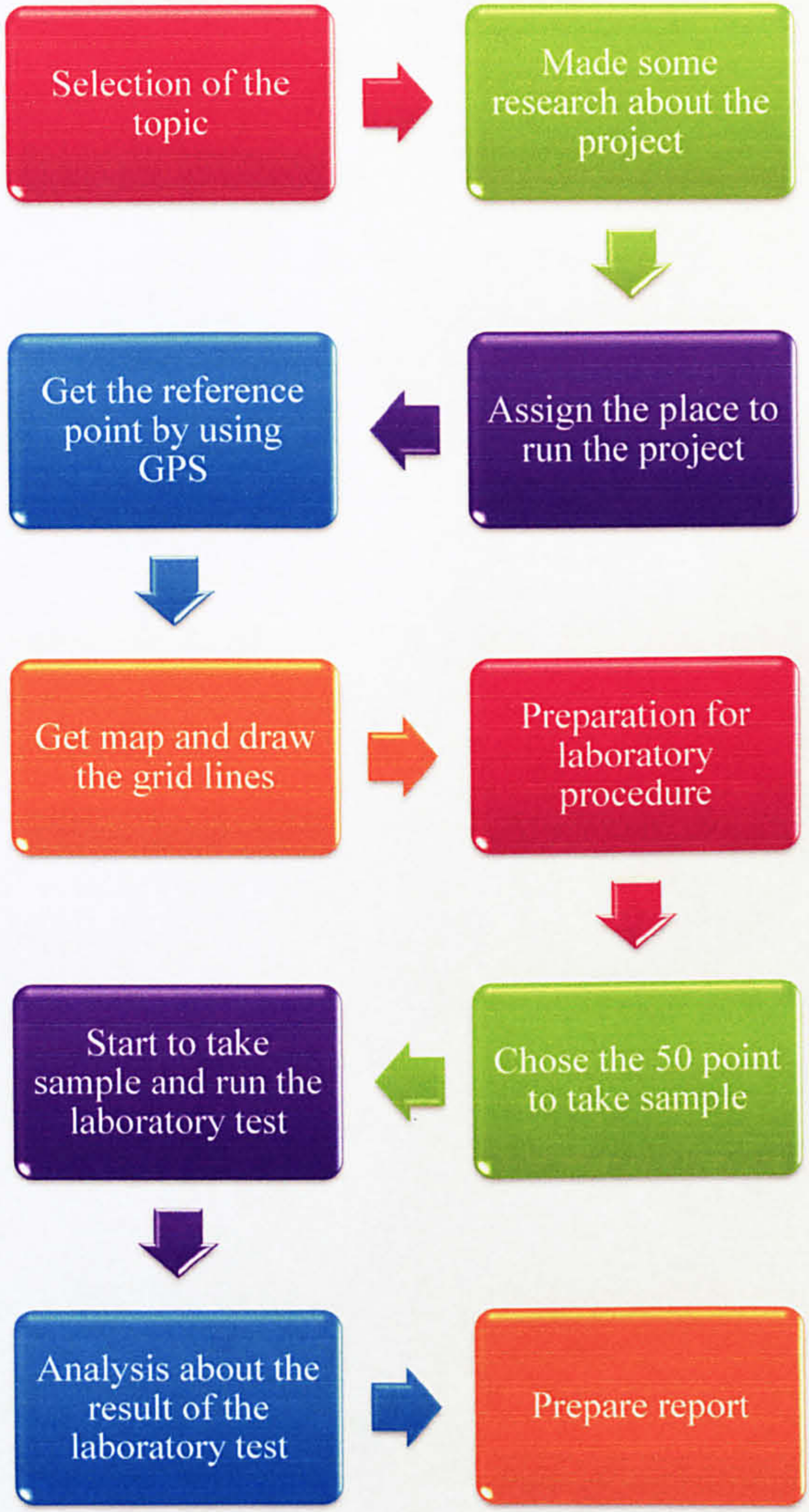
APPENDICES

Flow diagram of the project



Appendix - 2

Gantt chart for Final Year Project 1

No.	Detail/Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
1	Selection of Project Topic																
2	Preliminary Research work																
3	Submission of Premilinary																
4	Seminar (optional)																
5	Project Work																
6	Submission of Progress report																
7	Submission of Interim Report Final Draft																
8	Oral Presentation																

progress

suggested milestone

Appendix - 2

Gantt chart for Final Year Project 2

No.	Detail/Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Project work continue -soil sampling -laboratory analysis	■	■	■	■	■	■	■	Mid-semester break	■	■					
2	Submission of progress report 1				□											
3	Submission of progress report 2									□						
4	Project work continue - statistical and geostatistic analysis									■	■	■	■			
5	Preparing poster and oral presentation, dissertation report										□					
6	Poster Exhibition											□				
7	Submission Of Dissertation (soft bound)													□		
8	Oral Presentation														□	
9	Submission Of Dissertation (hard bound)															□

□ Suggested milestone

■ Progress

Table 2: Data of permeability

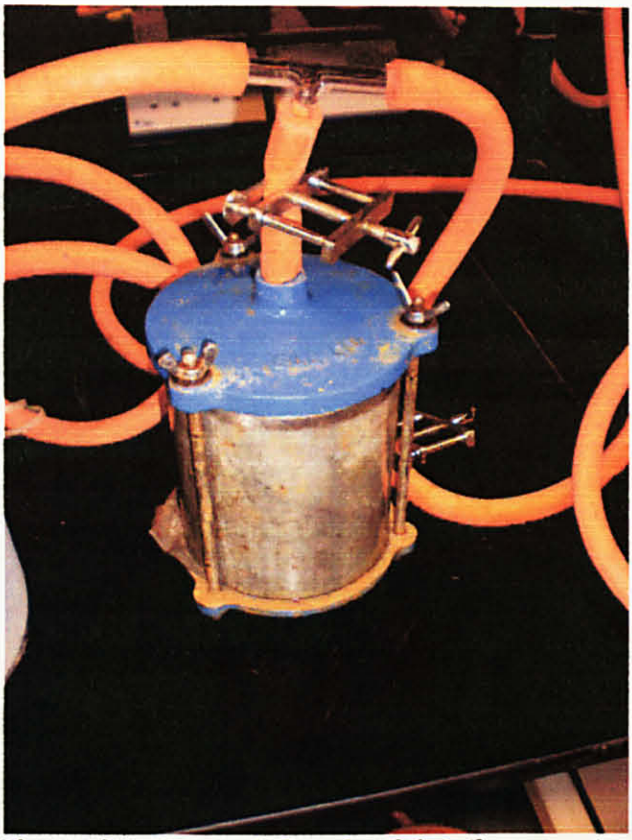
(L) Height of soil sample = 120
(V) Change of volume = 60
(h1) Height of water at t0 = 90
(h2) Height of water at t = 30

Sample no	X-coordinate	Y-coordinate	Coordinate	(A) Cross section of sample	(t) Time	(K) Permeability (mm/h)
1	100°57'50"	4°22'55"	J7	7853.98	20	81.2763
2	100°57'50"	4°22'50"	J8	7853.98	2060	0.7891
3	100°57'45"	4°23'10"	I4	7853.98	1514	1.0737
4	100°57'45"	4°23'15"	I5	7853.98	1742	0.9331
5	100°57'50"	4°23'20"	J2	7853.98	657	2.4742
6	100°57'55"	4°23'20"	K2	7853.98	380	4.2777
7	100°58'0"	4°23'20"	L2	7853.98	815	1.9945
8	100°57'50"	4°23'15"	J3	7853.98	616	2.6388
9	100°57'45"	4°23'5"	J5	7853.98	1096	1.4831
10	100°57'45"	4°23'0"	H6	7853.98	1124	1.4462
11	100°57'45"	4°22'55"	H7	7853.98	992	1.6386
12	100°57'45"	4°22'50"	H8	7853.98	817	1.9896
13	100°57'45"	4°22'40"	I10	7853.98	1213	1.3401
14	100°57'50"	4°22'40"	J10	8413.38	754	2.0125
15	100°57'55"	4°22'45"	K9	7853.98	1575	1.0321
16	100°58'0"	4°22'45"	L9	8413.38	1621	0.9361
17	100°57'55"	4°22'50"	K8	7853.98	675	2.4082
18	100°58'0"	4°22'50"	L8	8413.38	2758	0.5502
19	100°57'55"	4°22'55"	K7	7853.98	405	4.0136
20	100°58'0"	4°22'55"	L7	8413.38	772	1.9656
21	100°58'35"	4°23'15"	S3	7853.98	537	3.0270
22	100°58'40"	4°23'15"	T3	8413.38	644	2.3563
23	100°58'40"	4°23'10"	T4	7853.98	496	3.2773
24	100°58'35"	4"23'10"	S4	8413.38	702	2.1616
25	100°58'45"	4°23'10"	U4	7853.98	296	5.4916
26	100°58'35"	4°23'5"	U3	8413.38	156	9.7272
27	100°58'40"	4°23'5"	T5	7853.98	372	4.3697
28	100°58'45"	4°23'5"	U5	8413.38	696	2.1802
29	100°58'30"	4°23'5"	R5	7853.98	741	2.1937
30	100°58'35"	4°23'5"	S5	8413.38	453	3.3498
31	100°58'20"	4°23'15"	P3	7853.98	663	2.4518
32	100°58'25"	4°23'15"	Q3	8413.38	615	2.4674

33	100°58'20"	4°23'10"	P4	7853.98	562	2.8924
34	100°58'15"	4"23'10"	O4	8413.38	785	1.9331
35	100°58'20"	4°23'5"	P5	7853.98	236	6.8878
36	100°58'25"	4°23'5"	Q4	8413.38	371	4.0901
37	100°58'15"	4°23'5"	O5	7853.98	854	1.9034
38	100°58'15"	4°23'0"	O6	8413.38	738	2.0562
39	100°58'10"	4°23'15"	N3	7853.98	613	2.6518
40	100°58'10"	4"23'10"	N4	8413.38	694	2.1865
41	100°58'5"	4°23'10"	M4	7853.98	742	2.1907
42	100°58'5"	4°23'5"	M5	8413.38	921	1.6476
43	100°57'55"	4°23'15"	K3	7853.98	1554	1.0460
44	100°57'50"	4°23'10"	J4	8413.38	1711	0.8869
45	100°57'55"	4°23'5"	K5	7853.98	642	2.5320
46	100°58'0"	4°23'5"	L5	8413.38	883	1.7185
47	100°58'20"	4°22'55"	P7	7853.98	44	36.9438
48	100°58'15"	4°22'55"	O7	8413.38	18	84.3025
49	100°58'30"	4°23'0"	R6	7853.98	140	11.6109
50	100°58'30"	4°22'55"	R7	8413.38	86	17.6447

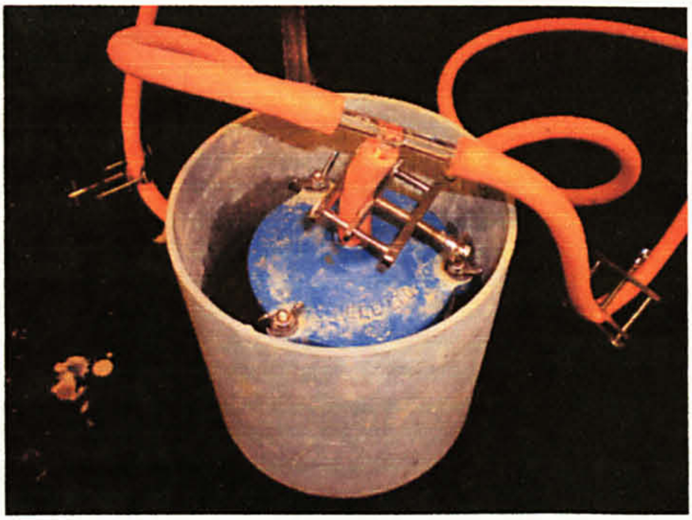
Data of Permeability

Appendix - 4



Setting up the apparatus before place it into the compartment

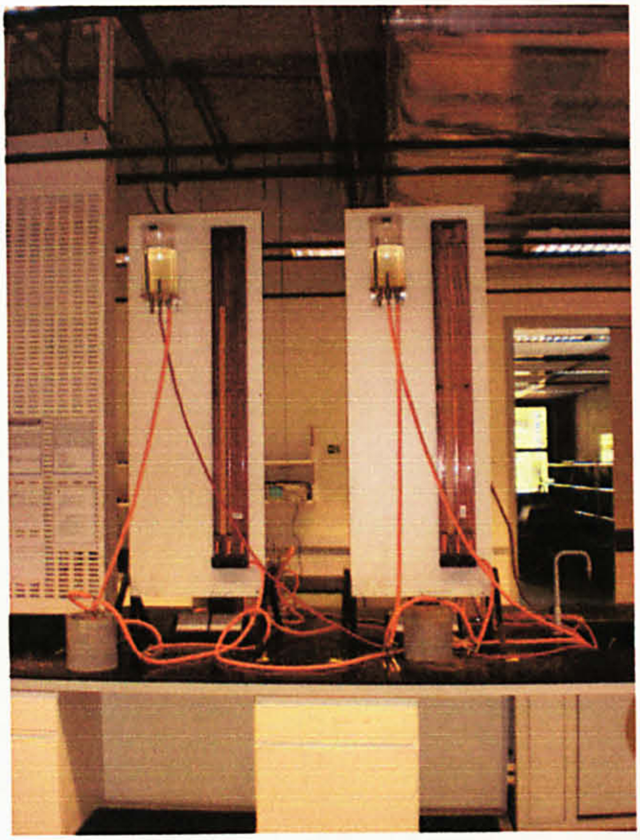
Both mould that use for falling head test



After place into the special compartment

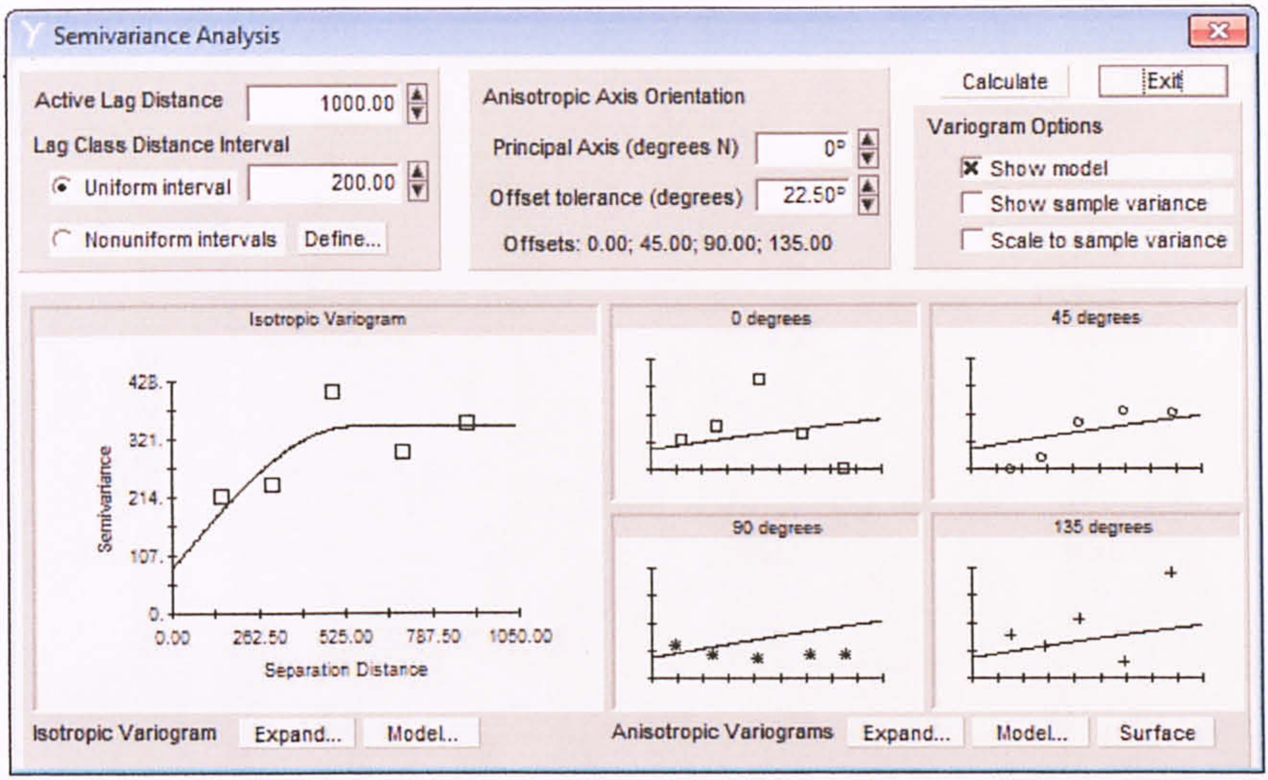
During taking the sample

Appendix - 4



During laboratory test underway

Appendix - 4



Semivariance analysis

Isotropic Variogram Model

Model	Nugget Co	Sill Co + C	Range Parameter Ao	Effective Range	Proportion C/(Co+C]	r2	RSS
Spherical	82.90000	344.50000	544.0000	544.0000	0.759	0.638	9420.
Exponential	59.10000	356.30000	220.0000	660.0000	0.834	0.559	11441.
Linear	213.33392	367.19478	895.3096	895.3096	0.419	0.406	24177.
Linear to sill	123.60000	348.00000	490.0000	490.0000	0.645	0.715	7414.
Gaussian	150.10000	346.60000	515.0000	892.0062	0.567	0.610	10119.

Refit | Apply | Print | Cancel | Exit

Isotropic Variogram Model